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NWC TP 4501

GEOLOGIC EVALUATION OF SAN CLEMENTE ISLAND AS A LOCATION FOR A ROCK-SITE I INSTALLATION

by

C. F. Austin

Research Department

ABSTRACT. San Clemente Island has been studied to determine the geologic suitability of employing the island as a candidate site for the construction of a Rock-Site I installation, the land-linked experimental laboratory. The studies of the island consisted of a review of the geologic literature, aerial reconnaissance, geologic mapping, core drilling, borehole pumping, and offshore geophysical studies and sampling operations. Based on the results of these investigations the recommendation is made that the laboratory area beneath the sea floor be located off Mail Point with access tunnels to the laboratory originating at either Mail Point or Lost Point. Although Rock-Site I laboratory construction is believed to be technically feasible at San Clemente Island, the proposed undersea installations will encounter major inflows of saline water from the volcanic host rock, requiring grouting or other water control measures; the access to the water mass will be limited to either shallow shelf areas or to water depths of the order of 1,250 feet or more because of sediments in the offshore areas; and site engineering will be hampered by the apparent steep seaward dip that develops in the offshore andesites. As a candidate site, San Clemente Island is considered to be feasible but difficult.

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FOREWORD

This report presents the conclusions of Dr. Carl F. Austin, the originator of the Rock-Site concept, upon the feasibility of constructing a Rock-Site installation at San Clemente Island.

The various supporting studies upon which this evaluation is based were conducted during the interval of 1965 through 1967, beginning as a program at the U. S. Naval Ordnance Test Station, and completed as programs of both the Naval Undersea Warfare Center, Pasadena, California, and the Naval Weapons Center, China Lake, California. This concluding study, performed at this Center, was supported by Independent Exploratory Development, Director of Laboratory Programs Task Assignment Z-F008-98-01.

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INTRODUCTION

Rock Site is the concept of placing large one-atmosphere manned installations within the rock mass of the sea floor. The generalized Rock-Site concept has been described in both Navy and open literature publications (Ref. 1-3), mining industry applications have been discussed (Ref. 4), and petroleum industry applications presented (Ref. 5). Given the technically feasible general concept of Rock Site, the concept studies can then be broken into the following units: Rock Site I, which is a land-linked laboratory; Rock Site II, which is an isolated shelf or seamount laboratory; and Rock Site III, which is an isolated deep-sea or under-ice installation. This report examines one proposed location for a Rock-Site I land-linked installation.

To be studied in detail, a candidate site should be Navy-owned, should have volcanic geology, and should preferably be at an easily accessible and easily supportable location. With San Clemente Island predominantly volcanic rock in geology and owned at that time by the U. S. Naval Ordnance Test Station, at which the Rock-Site concept was developed, the island was a very logical candidate site for an initial investigation. Figure 1 is an index map showing the location of San Clemente Island in relation to the southern California industrial and oceanographic centers of Los Angeles and San Diego. Figure 2 presents the principal present-day development on San Clemente Island (see Ref. 6 for details of the island's installations).

DATA DEVELOPED

The following sections present abstracts of the available and pertinent data on the geology of San Clemente Island. Those persons wishing to pursue the subject of the geology of San Clemente Island as a candidate site in greater detail are urged to explore the references in detail. As this report is intended as a technical opinion rather than a recounting of the available data, only abstracts and conclusions from various reports are included.

PUBLISHED GEOLOGY

An excellent paper describing the geology and general physiography of San Clemente Island was prepared by Smith (Ref. 7). A more recent

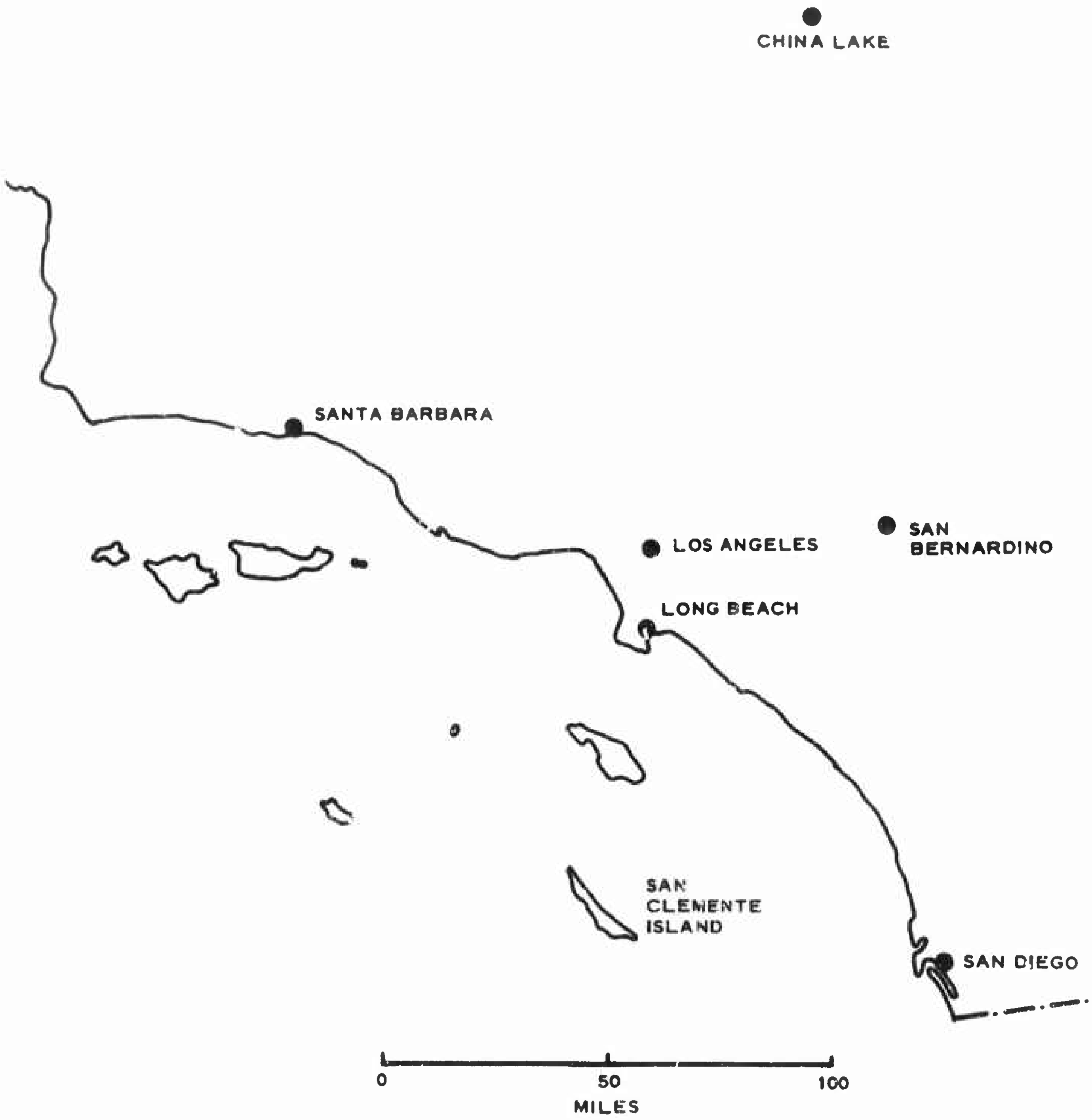

FIG. 1. San Clemente Island in Relation to Major Southern California Cities.

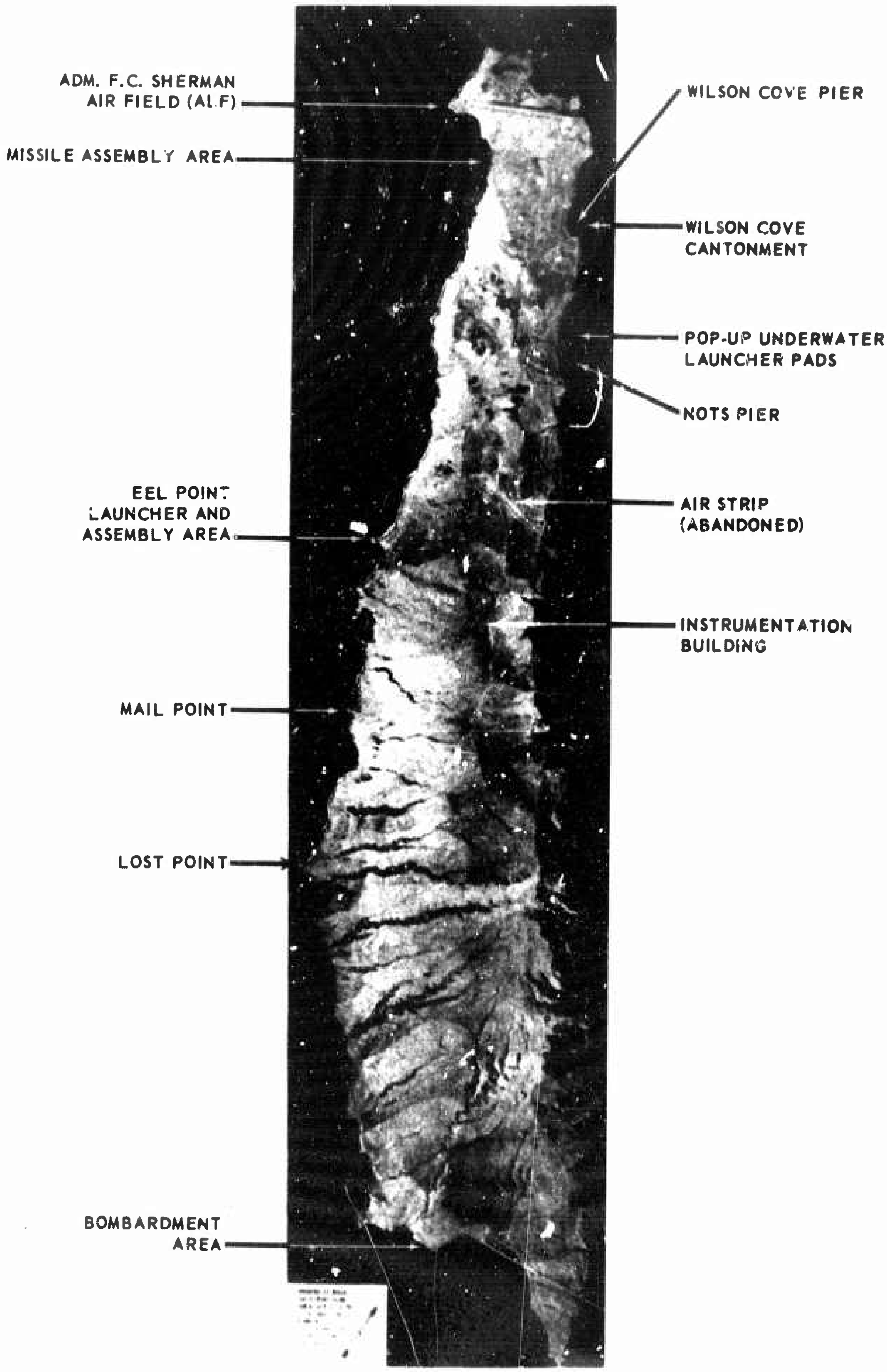

FIG. 2. Photomosaic of San Clemente Island Showing the Location of Eel, Mail, and Lost Points, and Major Developed Areas.

paper by Olmsted provides a concise summary of the island's general geology (Ref. 8). The following is Olmsted's abstract:

> "San Clemente Island, which is the southernmost of the channel islands lying off the coast of southern California is a gently arched and faulted block of the earth's crust composed principally of volcanic rocks. The volcanic rocks are chiefly pyroxene andesite flows and pyroclastic rocks which are overlain by relatively thin flows of dacite and rhyodacite or rhyolite. Overlying or interbedded with the upper part of the volcanic sequence are thin, discontinuous masses of marine sedimentary rocks which contain abundant fossils of probable middle Miocene age. The youngest deposits on the island are older sand deposits of probable Pleistocene age and younger sand deposits and alluvial-fan deposits of Recent age. Marine terrace deposits, soil, and landslide deposits are extensive but thin and generally were not mapped.
>
> "The San Clemente Island block is bounded on the northeast by a major fault--the San Clemente fault--on which the movement may have been chiefly horizontal. The volcanic rocks of the island are deformed by a gentle domal or anticlinal structure whose axis is approximately parallel to the San Clemente fault. In addition, the rocks are cut by a system of relatively small faults that trend approximately north and also by a set trending N20° - 30°W."

One of Olmsted's cross sections of the island is presented in Fig. 3. This type of island profile immediately suggests the mainland side of the island as the most attractive location, since access to deep water can be achieved very close to shore. Unfortunately, even the most rudimentary field examination of the island on the mainland side proves the main landside of the island to be the site of extensive landslide action.

GEOLOGIC RECONNAISSANCE

The island was next studied on air photographs and directly from the air, using both fixed wing aircraft and helicopters. This reconnaissance immediately showed that the mainland side of the island consisted to a considerable degree of slump blocks, some of which give the appearance of still actively sliding into the ocean. Figure 4 shows an aerial photograph of a typical slump area located on the central mainland side of the island. As a result of the instability of the steep side of the island, the ocean side of the island was next studied. The offshore topography published for the island suggested that the area between Eel and Lost Points would provide a suitable water depth of 1,000 feet within a few miles of shore. Eel Point appeared to be the best site, based on reconnaissance, having a deep narrow submarine canyon indicated offshore

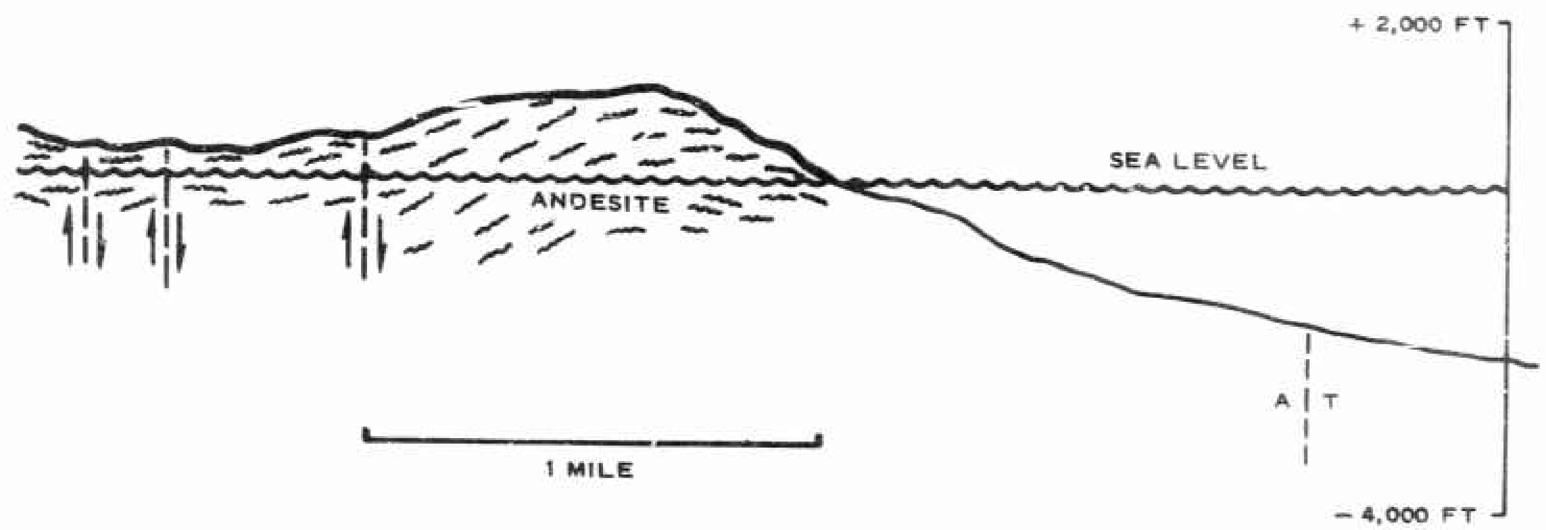

FIG. 3. Cross Section of the Mainland Side of San Clemente Island Near the Southern End of the Island (from Ref. 8).

FIG. 4. Aerial Photograph of Central Eastern Portion of San Clemente Island Showing a Prominent Slump Zone (Marked by Arrow).

bringing deep water in relatively close, having good access by road, and a broad expanse of working room for drilling and construction installations. Lost Point and Mail Point, the latter nearly midway between Eel and Lost Points (Fig. 2), also presented good working room, that is, a large expanse of flat ground at sufficient height above sea level (+ 50 feet) to preclude serious objections based on possible tsunami hazards. At this time neither Mailnor Lost Points were served by an existing road. Following the reconnaissance program, a temporary dirt road was constructed to Lost Point. This point was chosen as the second possible location on the island, based on both a reasonable offshore topography and on its distance from Eel Point. This latter aspect, distance, was desired in the event that suggested cross island faulting based on photographic interpretations combined with the extensive en echelon tensile faulting of the island should make the Eel Point location unacceptable, that is, the second site would be a considerable distance away and thus hopefully involved with a different set of faults. These points were selected over straight coastline in hopes that such seaward projections would represent locally more competent rocks, that is, less fracturing plus seaward scour that might give less loose alluvium on the sea floor.

A 4-square-mile area of the coast was then selected at each point for further geologic investigation. An area of this size was believed to provide a sufficient statistical base for reliably predicting the frequency and attitude of locally important faults, flow attitudes, and joint frequency.

DETAILED STUDIES OF EEL AND LOST POINTS

The detailed geologic studies of the Eel Point and Lost Point areas were for the determination of several geologic factors: (1) whether or not any of the prominent marine terraces and wave-cut slopes present near the proposed sites were in reality the expression of underlying slump blocks, and (2) which of the two points showed the most promise as an access shaft site for a land-linked laboratory.

A contract was let with a consulting geology group for the study of the geology of these two areas of roughly 4 square miles each. The abstract of the resulting geologic report follows (Ref. 9):

> "Central San Clemente Island is underlain to unknown depth by andesitic and dacitic flows. A yellow-brown breccia, which is in part of sedimentary origin, is present over much of the area at the unconformity between the andesitic and the younger dacitic flows. On the western slope of the island, the flows are horizontal or dip gently seaward. All bedrock units are cut by faults, most of which trend north-northeast to northeast. Maximum separation amounts to a few hundred feet. Fault zones

are generally 1-15 feet in width, consisting of light-colored gouge and fault breccia. Most fault zones show evidence of groundwater percolation. Jointing is present throughout the flows but is most prevalent in the massive and platy flows; it is less well developed in the vesicular and brecciated flows. The average spacing of the joints is 6 inches to 2 feet. From an engineering geology standpoint, the Eel Point and Lost Point areas are equally appropriate for Project Rock Site."

General photographic views of Eel Point, Mail Point, and Lost Point are presented in Fig. 5-7. Since there was no onshore geologic suggestion that one area was better or worse than the other, all further shore-based geologic work was carried out at Eel Point because of the much easier access to this location. At this point, contracts were recommended for test borings at Eel Point and for general offshore detailed studies, with emphasis in the areas off both Eel and Lost Points.

EEL POINT CORE HOLE

A test core was desired that would be at least 1,200 feet deep. This depth was based on the initial Rock-Site I design that is shown in Fig. 8. This laboratory would consist of the following fundamental units: a vertical access shaft near the shoreline, a sump room, a power plant area, a laboratory area, and access locks at the sea floor at both 660 feet of ocean depth and at 1,000 feet of depth, with the latter an extension of the main haulage level. A test hole, yielding continuous coring, would answer a number of important questions including: (1) Will a deep installation on San Clemente Island strike oil? This possibility stems from three lines of evidence--the anticlinal or domed aspect of the island, the low gravity reported for the island that suggests a shallow depth to sediments, and reports of oil seeps.[1] A shoreline search failed to locate any oil seeps, but the shore is so heavily contaminated by oil and tar that finding any useful indications at present would be most unlikely. (2) Will a deep installation encounter hot geothermal fluids or volcanic gasses? This is a potential problem with any drilling done into relatively young volcanic terrains, especially adjacent to a major fault zone such as the San Clemente fault. (3) What strengths and competence of rock are present at depth? (4) Do volcanic rocks extend to a sufficient depth to keep the entire installation that has been proposed within volcanic rocks? (5) What water-inflow problems can be anticipated at depth?

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[1] Unpublished "History, San Clemente Island," by Robert A. Hume, 670th ACW Squad, San Clemente Island, July 1959.

FIG. 5. View of Eel Point Taken From Just Offshore.

FIG. 6. Aerial View of Lost Point.

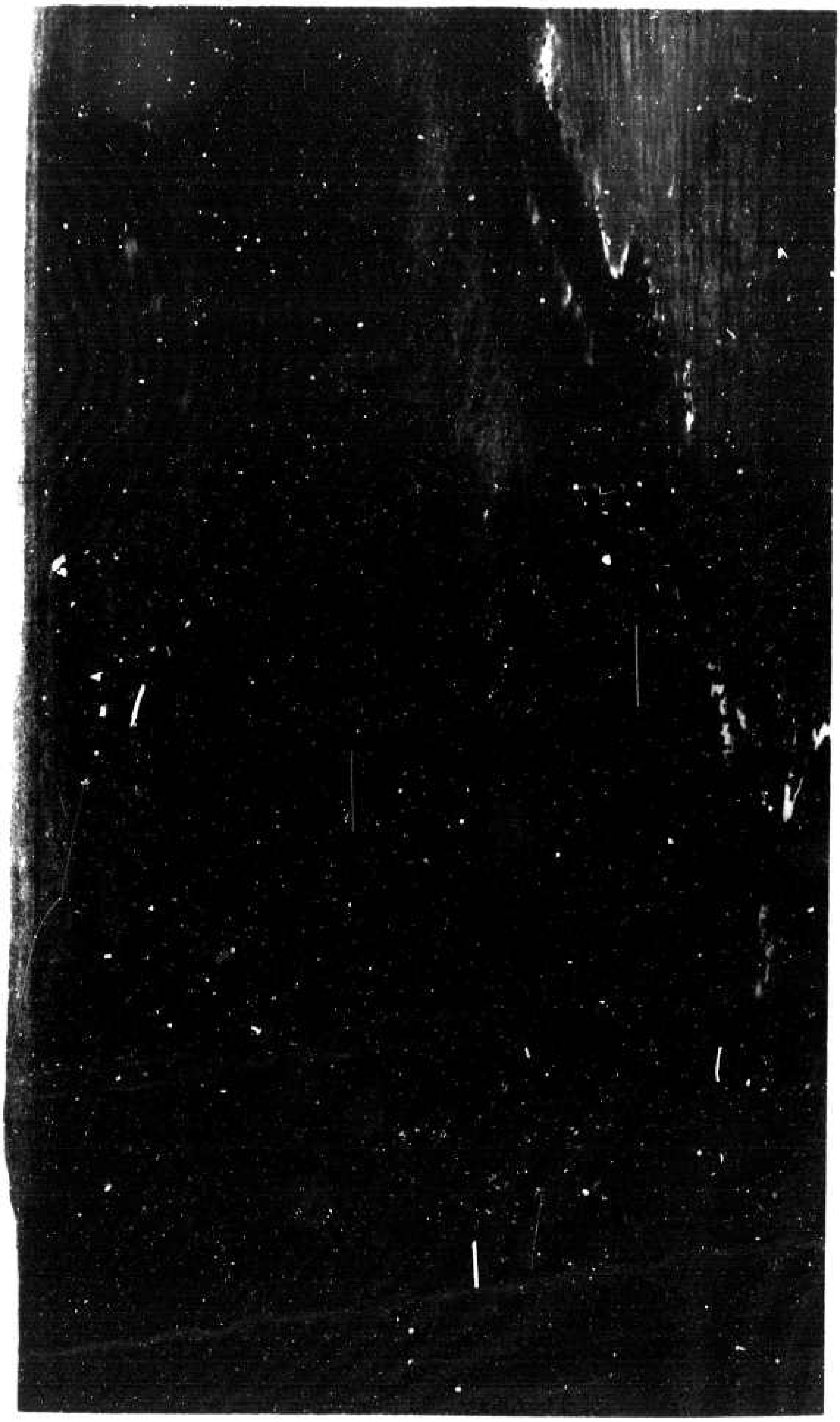

FIG. 7. Aerial View of Mail Point.

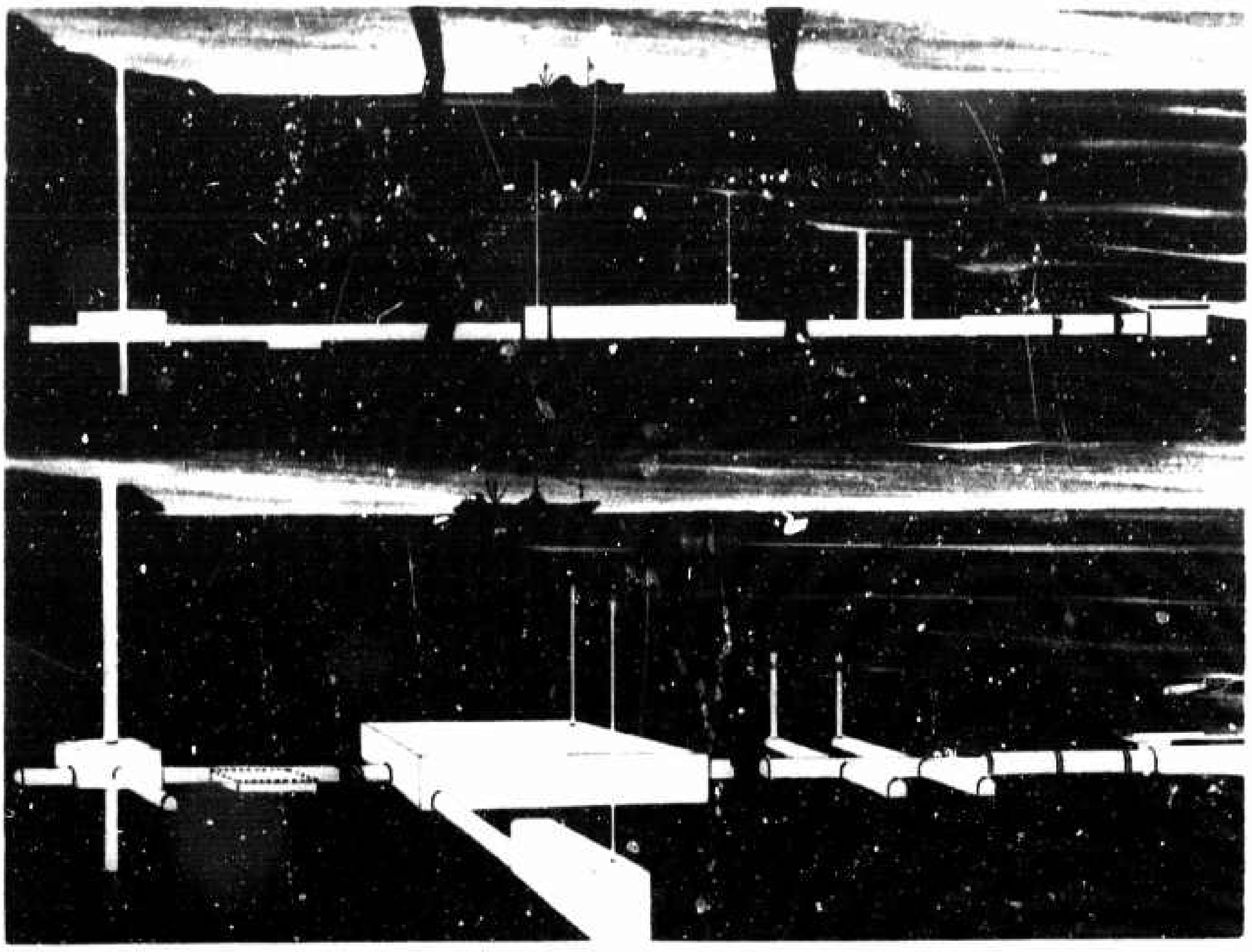

FIG. 8. Original Design Concept for Rock Site I Consisting of Access Shaft, Power Plant, Laboratory Area, and Lock Structures.

A contract was established to drill a continuously cored hole at Eel Point. Figure 9 shows the location of the test hole and Fig. 10 shows the drilling operation in progress. The hole was drilled to a depth of 48 feet at which point 6-inch casing was set, then drilled to a depth of 972 feet with a 5½-inch bit, and then on to 1,200 feet with a 3-7/8-inch bit using wireline equipment. Casing, consisting of 4-inch line pipe, was set and cemented to the 972-foot depth, with a cement return to the surface, although this drew back, probably due to failure of the permeable 4-foot-thick fault zone encountered between 78 and 82 feet. Coring was generally satisfactory, with a good recovery of core, although some circulation loss was experienced. The hole remained in volcanic rocks, was relatively free of gasses (emits a trace of H_2S that may be due to drilling mud additives), the hole was cool (about 75°F at the bottom), and there was no indication of petroleum leakage into the drill hole.

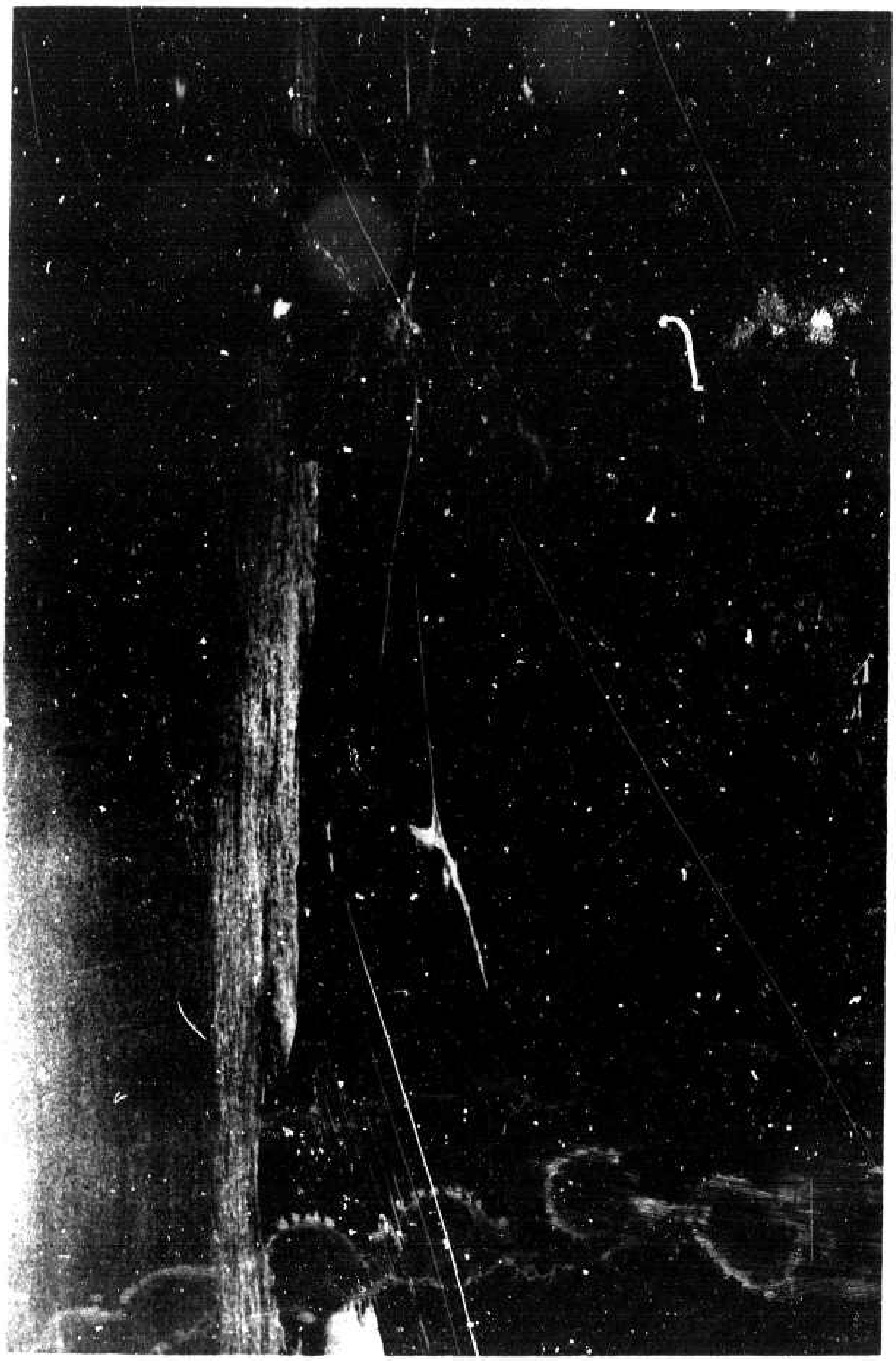

FIG. 9. Location of the Test Coring Operation at Eel Point. The arrow points to the drill rig for the test hole; Eel Point is to the left; the now abandoned Greek freighter, White Eagle, is just beyond the drill site.

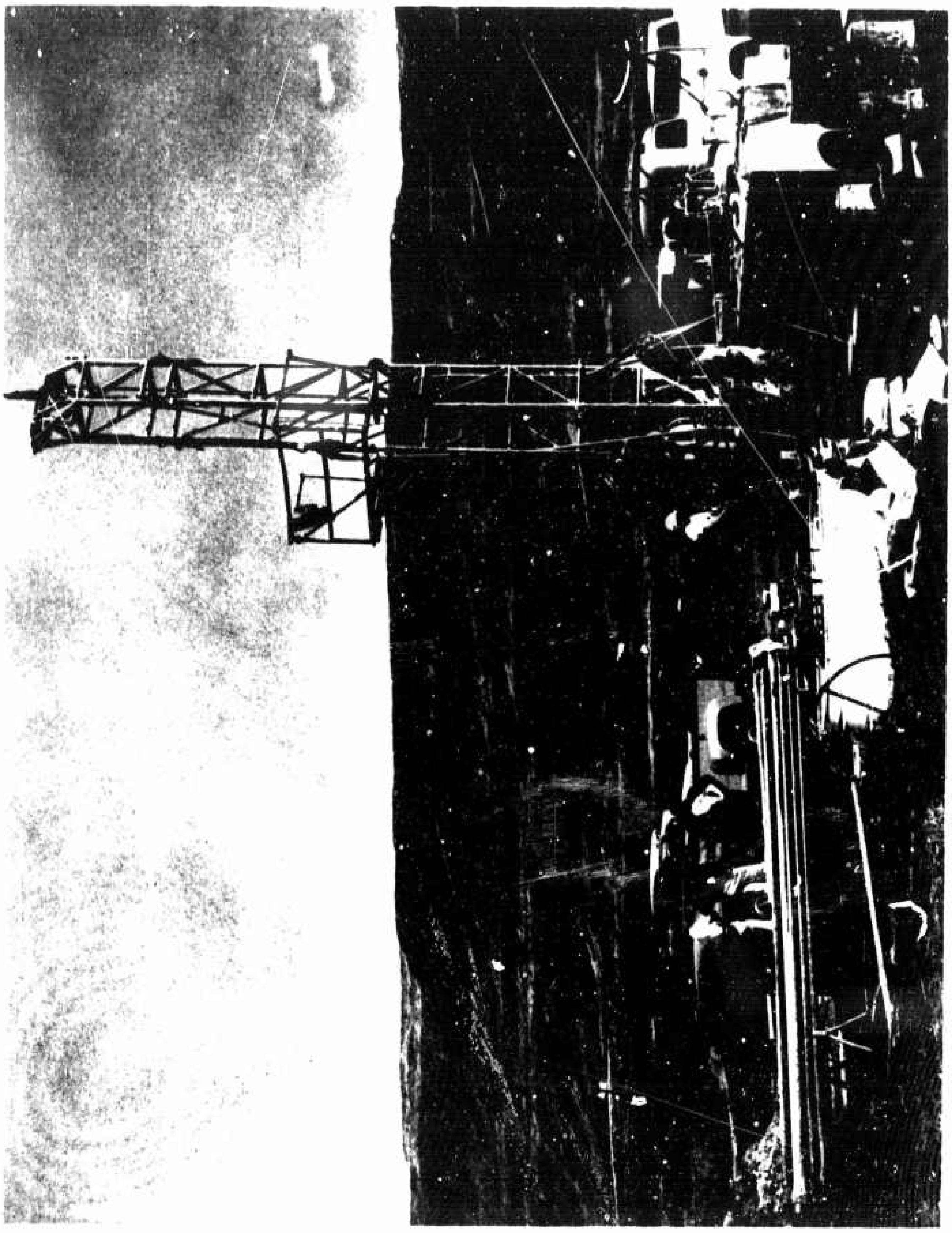

FIG. 10. Core Drilling to a Depth of 1,200 Feet in Andesite at Eel Point on San Clemente Island.

The drill core was initially logged by the prime contractor[2] of the drilling operation but a more detailed log was desired. This detailed logging was accomplished by contract and the results are being published (Ref. 10). Figure 11 shows the core laid out for the purposes of logging. As can be seen in Fig. 11, the core is quite competent though somewhat fractured. The following are the conclusions developed by the group of contractors that logged the core.

> "1. The cored section provides sound rock for excavation. The rocks in the interval 540 to 900 feet appear to be the soundest.
>
> "2. Water leakage and stability problems can be expected where the graphic log indicates faulting or decomposition and the tuff bed (760-762 feet).
>
> "3. At Eel Point the flows dip seaward between 10 and 30 degrees, therefore, rocks younger than those in the core hole will be encountered in the subsurface offshore.
>
> "4. Correlation of these flows in additional core holes will require detailed analysis, owing to the similarity in composition and texture of individual flows.
>
> "5. The potassium-argon dates, the uniformity of composition, and the absence of definite soil zones indicate the extrusion of the flows from a common magmatic source in less than one-half million years during Miocene time."

With the Eel Point core hole cased for the first 972 feet, a pumping program was desired that would establish the type and quantity of dissolved solids and gasses in the formation waters present; the temperature of the waters, since the hole could have been somewhat quenched by the use of large volumes of seawater as a drilling fluid; and that would indicate whether the hole should be considered dry or wet, that is, would a possibly high initial water flow rate into the drill hole rapidly fail or should the deeper volcanic rocks be considered a major fluid reservoir.

The drill hole proved to be a high-volume producer of saline waters, slightly more concentrated than normal seawater. That the hole proved wet is not surprising, for the open portion of the hole cuts several different andesite flows and the indications are that both interflow zones and areas of jointing may be water-producing. Although, when taken as a whole, the volcanic mass below the casing appears wet, there is still a reasonable probability that individual flow units, where massive, will

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[2] Unpublished "Final Report, Project Rock Site, San Clemente Island, California," by Buena Engineering, Ventura, Calif., 1967, under Contract N62437-67-C-0324.

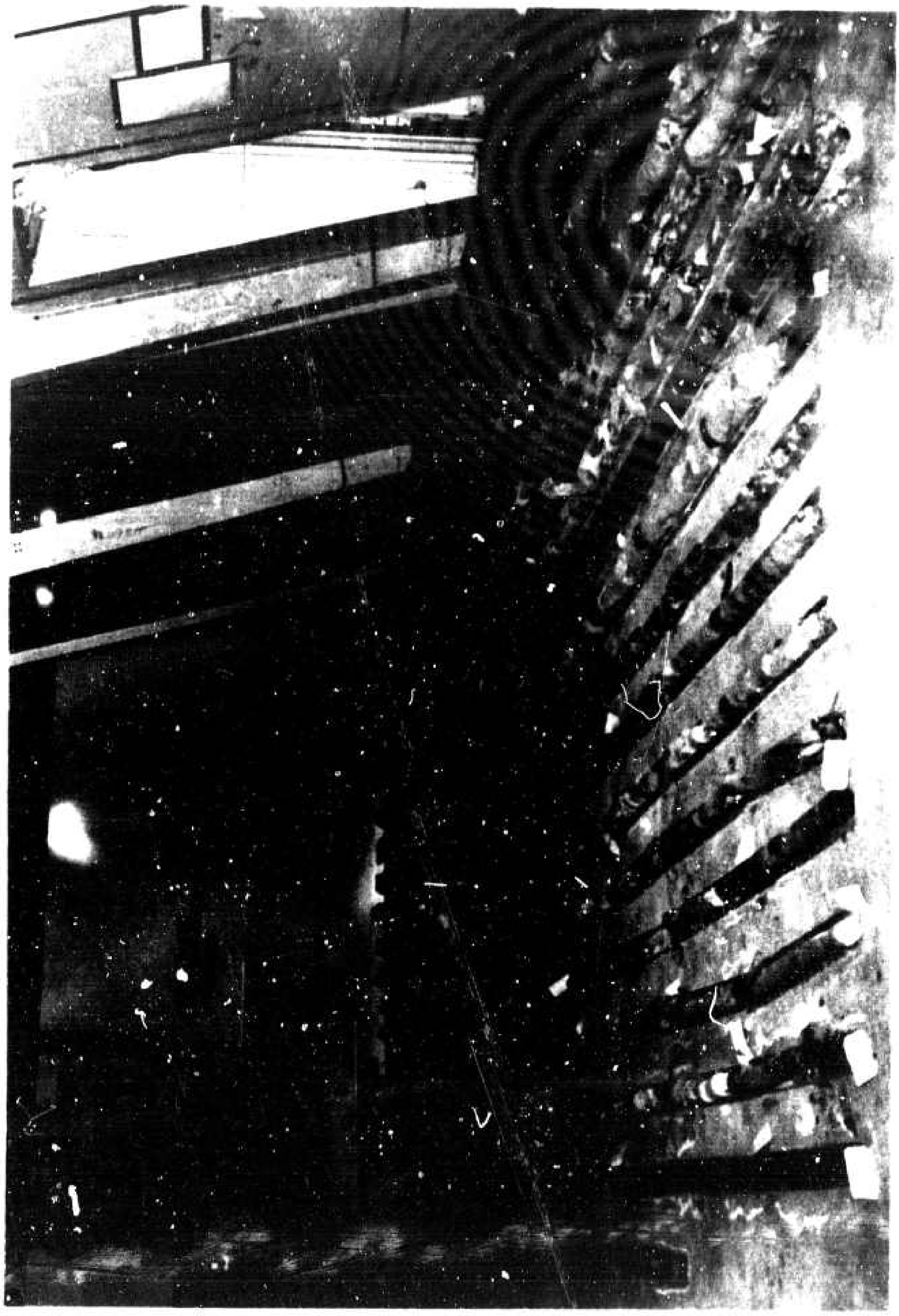

FIG. 11. Portions of the Core Recovered from the Eel Point Drill Hole. Core is 4 inches in diameter to a depth of 972 feet, then 2 5/8 inches in diameter to a depth of 1,200 feet.

show significantly less recharge potential than was demonstrated for the rock mass taken at large.

Interestingly, the water level in the drill hole at Eel Point showed what appeared to be slight tidal fluctuations (0.2 to 0.6 feet) with a time lag of 2.3 hours behind the local high tide. Although the consulting firm conducting the pumping tests assumed this meant interconnection between the ocean and the saturated rocks below the casing, this is pure supposition. A very intriguing hypothesis that could stand both field research and theoretical consideration is that the water level in the hole was showing a combined tidal loading and earth tide effect.

Continued pumping for several weeks allowed the fluids produced from the borehole to reach an apparent stability of composition, with a mildly acid pH due apparently to carbon dioxide, a slight odor of hydrogen sulfide (2 ppm), and a temperature of 75°F indicating comfortable rock conditions. Although corrosion of the pumping equipment was noted during the pumping program, the corrosion was not especially severe. The fact that these waters were very low in dissolved oxygen could mean an added load on any undersea life-support system attempting to operate in a closed ecology environment.

A final test conducted by the pumping contractor was to dump water into the well to ascertain if the well would accept fluids in any quantity. The well initially took some 43 gpm but shortly after refused any further water and failed to fluctuate tidally thereafter, leaving considerable doubt as to the hydrology of the exposed formations.

In general, the pumping test confirmed that the various volcanic flow contacts, highly jointed areas, and fault zones should be looked at with suspicion and considered water-producing until proven otherwise. The drill hole was too small to permit a large enough pump installation to yield meaningful drawdown tests with the water-flow potential found. No tests using packers to isolate selected areas in the hole were performed at this time. The pumping tests are summarized in an unpublished report.[3]

OFFSHORE STUDIES

Extensive offshore studies were performed to evaluate the offshore geology and to determine the bottom topography (Ref. 11). These studies involved continuous seismic profiling, geological diving, snapper sampling, and use of CURV (cable-controlled underwater research vehicle). The following conclusions were developed:

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[3] "Geotechnical Investigation of Rock Site Well No. 1," by Geotechnical Consultants, Inc., October 1967.

"1. A sequence of four sediment and rock units from Middle Miocene to Recent are referred to as Units A through D. Unit A is a sediment cover of Recent and possibly Late Pleistocene age. Unit B represents a post-Miocene, probably Pliocene-Pleistocene, accumulation of debris derived mainly from island canyons. Microfossils from submarine limestone outcrops indicate a Middle Miocene age from Unit C. Unit D is the offshore equivalent of the volcanic rocks exposed on the island.

"2. An offshore fault strike pattern is generally related to that of the adjacent part of the island. However, some of the offshore faults appear to be of the pivotal type. The pivotal faulting may be partly responsible for a submarine canyon off Eel Point. Furthermore, it may be responsible for sediment inliers north of Eel Ridge and Seal Cove areas.

"3. Isopach and structure maps readily show the offshore fault trend. This faulting along with erosional effects is responsible for a major unconformity between Units B and C.

"4. In general, faulting appears to have affected both Units C and D. Two faults are shown to have affected Unit B, but other evidence indicates that imcompetency within Unit B may be responsible for the lack of fault evidence on the profiles.

"5. A major insular terrace is present off the west side of the island that is postulated to have been wave-cut during Late Pleistocene to Recent time as a consequence of glacio-eustatic lowering of sea level. This terrace is at slightly over 100 meters below sea level and has been affected by Recent tectonism.

"6. CURV-vehicle photographs suggest marked differences in the velocity and direction of sea-floor currents in parts of the study area."

In hindsight, the fact that the shoreline drill site was selected prior to the interpretation of the offshore geophysical data is regrettable, as the hole would be of greater geologic value if at a location near Mail Point or else at Lost Point.

Because of the complexity of the geologic data that have been gathered, a three-dimensional plastic model was desired that would display all of the existing data developed for San Clemente Island in such a way as to facilitate an understanding of the structural and geologic framework of the island. A contract was let for the fabrication of such a model. Figure 12 shows a generalized view of the model. A study of this model showed that to go undersea from Eel Point would require the crossing of a major inferred undersea faulted area and that to reach the

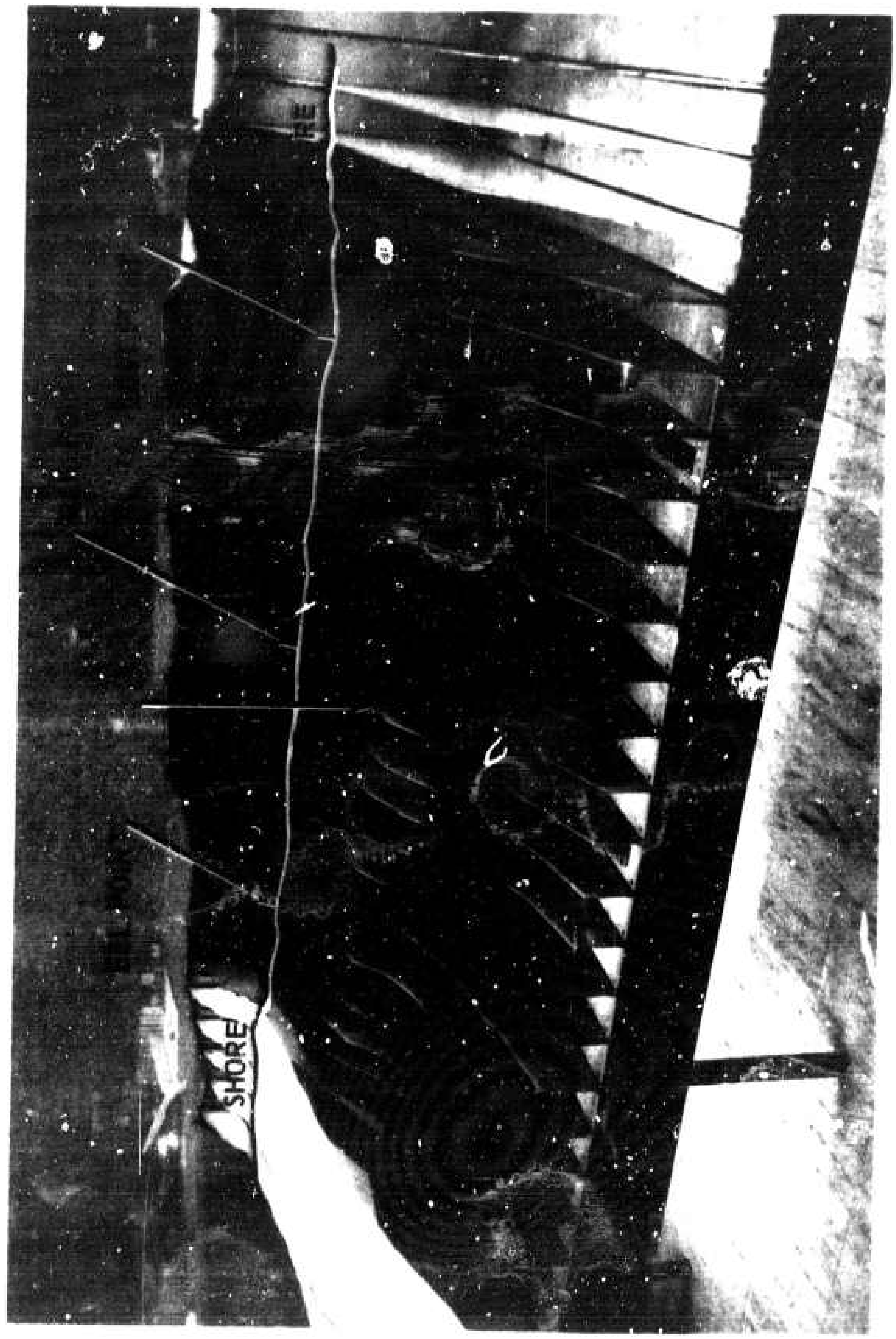

FIG 12. Three-Dimensional Plastic Model of a Portion of the Ocean Side of San Clemente Island. Vertical arrow marks attempted drill hole off Mail Point.

sea floor at any of the planned lock-tube depths would require tunnelling and construction in weak to unconsolidated sediments. Eel Point was thus abandoned as a potential location, for despite a very favorable topography, the undersea geology adjacent to Eel Point is very unfavorable.

Continuing with the study of the model plu he available detailed data, the sea floor immediately off Mail Poi would appear to be favorable, having a reasonable water depth (1,200-1,500 feet) accessible through volcanic rocks, and no obvious large fault zones or areas of geologic uncertainty such as the sedimentary bed offsets seen adjacent to Eel Point. With an undersea laboratory located off Mail Point, access can then be by tunnel from a drilled shaft at the shoreline near either Mail or Lost Points. The location actually employed would depend on the sea-floor fracture pattern and the joint pattern-stress field considerations within the projected tunnel route. Figure 13 shows a cross section of this area.

An offshore drill hole was then attempted off Mail Point, at the location shown in Fig. 12. This offshore drill hole was attempted with equipment that was unable to cope with the caving of the uppermost portions of the drill hole. This hole did confirm the suspicion that tunnelling or boring in the sediments offshore would need to be approached with great caution, both deep within these sediments and during lock-tube emplacement at the sea floor.

CONCLUSIONS

Based on the geologic evidence in hand, the author makes the following conclusions and recommendations:

1. A land-linked laboratory (Rock Site I) is technically feasible on the open ocean side of San Clemente Island.

2. Volcanic rock exposures on the open ocean side of San Clemente Island would permit access to the water mass at depths of 1,250 feet in the vicinity of Mail Point.

3. Access tunnels should run seaward from either Mail Point or from Lost Point, with the actual route depending upon the findings of detailed fault and joint pattern studies.

4. The andesitic rocks of San Clemente Island are sufficiently competent to permit tunnelling as well as soft enough to permit drilling and tunnel boring with existing industrial machinery. These rocks can cause trouble in both drilling and boring due to close joint spacing and due to internal stresses caused by their proximity to the San Clemente

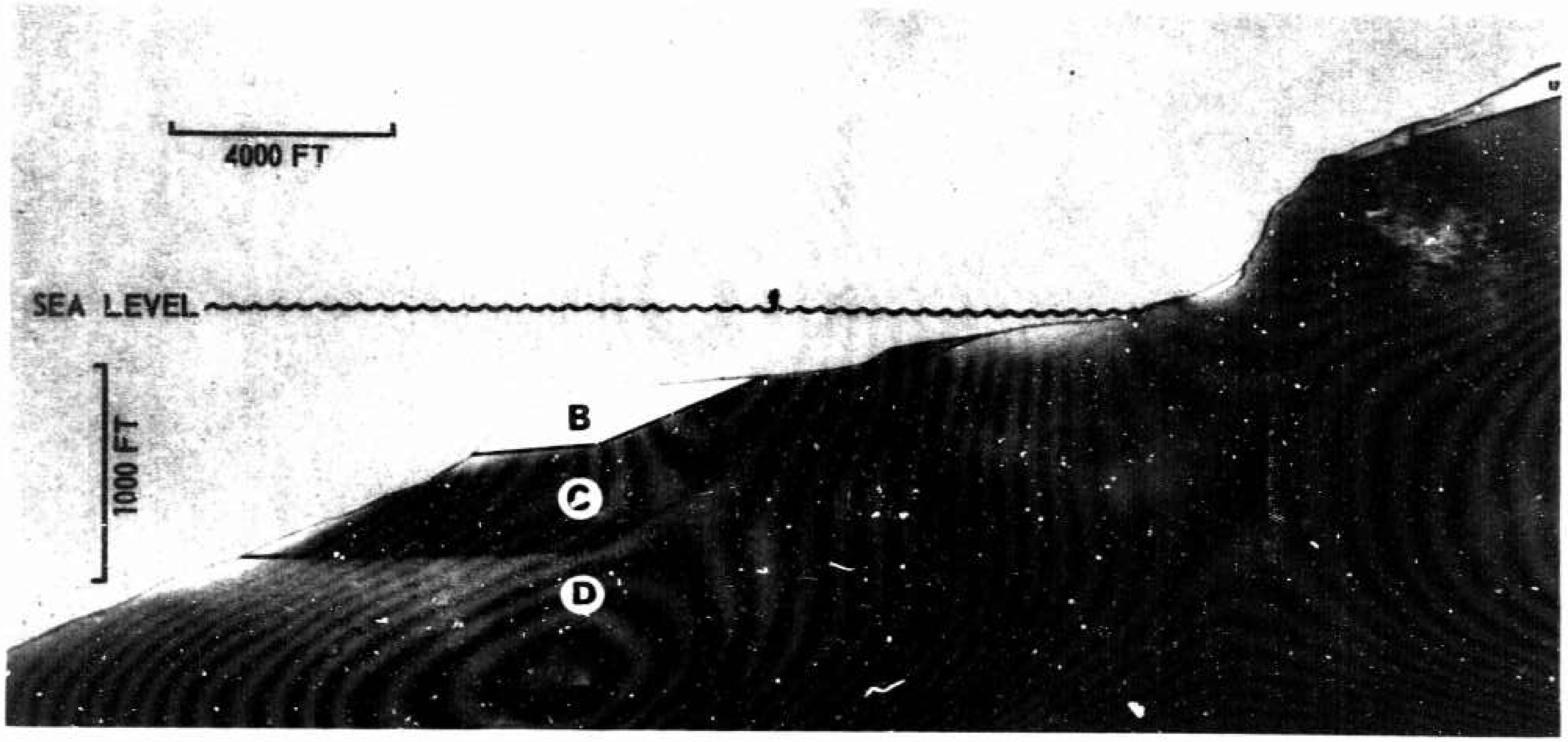

FIG. 13. Geologic Cross Section of Panel 17 of the San Clemente Island Model, Showing the Geology off Mail Point Where a Rock-Site I Installation is Recommended.

fault. (Vertical splits occurring in the core from Eel Point have been explained by some investigators as the result of stress relief.)

5. Water inflows are to be expected at all interflow horizons, in fault zones, and in joints. The recovered core from Eel Point was sufficiently fresh and free of alteration on joint surfaces so that clay mineral sealing would appear to be insignificant, although some minor sealing is observable in surface fault gouge exposures. Typical sealed volcanic rocks of the type seen in subaqueous flows and deposits studied at other localities are not present at San Clemente Island. However, the rocks present are strong enough so that erosion during high water inflows should not be a significant hazard.

6. The general freedom of the San Clemente Island andesites from oxide and sulfide coatings indicates that successful grouting practices can be devised to control and stop water inflows in these rocks.

7. Selection of the actual laboratory site and the access route from the shoreline shaft to the laboratory should be based on the following minimum investigatory program:

Determine the detailed shore geology of the entire area from Eel Point to Lost Point to provide geologic coverage of the area not previously mapped. This should be done at same scale as present detailed maps of Eel and Lost Points.

Conduct highly detailed offshore seismic and visual studies of the access tunnel route, the laboratory area, and the planned area of undersea lock-tube emplacement off Mail Point. This should provide detailed fault and joint data plus outcrop samples from the offshore volcanic rock exposures for age determinations.

Drill an offshore drill hole into the laboratory site, recover core for geomechanics studies and cement the hole on completion.

Core-drill to the planned tunnel horizon at a point midway to shore from laboratory for attempted horizon correlation and to yield core for geomechanics studies. Cement the hole on completion.

Core-drill the selected shoreline borehole site, then ream the core hole to 12 inches. Study the core for drilling and circulation problems, select the actual laboratory level desired, and conduct pumping tests on the volcanic horizons of interest.

8. Other possible sites on San Clemente Island could be chosen. The most attractive alternate areas, based on present information, are (1) northwest of Eel Point, which would require an unduly long access tunnel, and (2) one of the more stable appearing areas on the mainland side of the island that would require considerably greater drilling depths

for the shoreline access shaft and that would require very careful instrumentation of the rock mass utilized to ensure against active slump block movement, which would damage the undersea installations.

9. As a candidate site for a land-linked laboratory, Rock Site I, the ocean side of San Clemente Island in the vicinity of Mail and Lost Points can be considered a technically feasible but difficult location.

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Director of Laboratory Programs Naval Material Command Washington, C. D. 20360

13. ABSTRACT

San Clemente Island has been studied to determine the geologic suitability of employing the island as a candidate site for the construction of a Rock-Site I installation, the land-linked experimental laboratory. The studies of the island consisted of a review of the geologic literature, aerial reconnaissance, geologic mapping, core drilling, borehole pumping, and offshore geophysical studies and sampling operations. Based on the results of these investigations the recommendation is made that the laboratory area beneath the sea floor be located off Mail Point with access tunnels to the laboratory originating at either Mail Point or Lost Point. Although Rock-Site I laboratory construction is believed to be technically feasible at San Clemente Island, the proposed undersea installations will encounter major inflows of saline water from the volcanic host rock, requiring grouting or other water control measures; the access to the water mass will be limited to either shallow shelf areas or to water depths of the order of 1,250 feet or more because of sediments in the offshore areas; and site engineering will be hampered by the apparent steep seaward dip that develops in the offshore andesites. As a candidate site, San Clemente Island is considered to be feasible but difficult.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Rock Site I Manned undersea installation San Clemente Island geology Land-linked laboratory						

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